CLAIMS

1. A method for inspection of a sample, comprising:

irradiating the sample with a polychromatic beam of X-rays, comprising X-ray photons having a range of respective photon energies;

receiving the X-rays scattered from the sample at a plurality of scattering angles using one or more sensors, which generate output signals indicative of the respective photon energies of the X-rays photons that are incident thereon; and

analyzing the output signals based on the photon energies so as to determine a scattering profile of the sample at a selected photon energy within the range.

2. The method according to claim 1, wherein irradiating the sample comprises collimating the beam of X-rays.

3. The method according to claim 1, wherein analyzing the output signals comprises determining the scattering profile at selected, first and second photon energies within the range.

4. The method according to claim 3, wherein irradiating the sample comprises generating the beam using an X-ray tube having an anode comprising an anode material, wherein the first and second photon energies correspond to first and second atomic emission lines of the anode material.

5. The method according to claim 4, wherein the anode material comprises first and second elements, which generate the first and second atomic emission lines, respectively.

6. The method according to claim 1, wherein receiving the X-rays comprises receiving the scattered X-rays using an array of detector elements, arranged so that each of the elements receives the scattered X-rays at one of the plurality of scattering angles.

7. The method according to claim 6, wherein analyzing the output signals comprises counting X-ray photons that are incident on the detector elements at the selected photon energy.

8. The method according to claim 7, wherein counting the X-ray photons comprises reading out a charge generated in each of the detector elements due to the scattered X-rays that are incident thereon using a readout circuit that is common to a multiplicity of the detector elements.

9. The method according to claim 7, wherein counting the X-ray photons comprises processing pulses that are generated by each of the detector elements due to the scattered X-rays that are incident thereon.

10. The method according to claim 6, and comprising receiving the X-rays reflected from the sample over multiple elevation angles using the array of detector elements, and analyzing the output signals based on the photon energies so as to determine a reflectometric profile of the sample at the selected photon energy.

11. The method according to claim 1, wherein analyzing the output signals comprises determining the scattering profile as a function of azimuthal angle in a plane of a surface of the sample.

12. The method according to claim 11, wherein analyzing the output signals comprises determining the scattering profile due to a porous surface layer that overlies a substrate of the sample, and estimating, based on the scattering profile, one or more characteristics of pores located within the porous surface layer.

13. The method according to claim 1, wherein the sample comprises a semiconductor wafer, and wherein analyzing the output signals comprises determining the scattering profile due to a thin film layer on the wafer.

14. A method for inspection of a sample, comprising:

irradiating the sample with a polychromatic beam of X-rays, comprising at least first X-rays and second X-rays having distinct, respective first and second photon energies;

detecting the first and second X-rays scattered from the sample at a plurality of scattering angles; and

analyzing the detected X-rays so as to determine a scattering profile of the sample at the first and second photon energies.

15. The method according to claim 14, wherein irradiating the sample comprises collimating the beam of X-rays.

16. The method according to claim 14, wherein irradiating the sample comprises generating the beam using an X-ray tube having an anode comprising an anode material, wherein the first and second photon energies correspond to first and second atomic emission lines of the anode material.

17. The method according to claim 16, wherein the anode material comprises first and second elements, which generate the first and second atomic emission lines, respectively.

18. The method according to claim 14, wherein detecting the first and second X-rays comprises receiving the scattered X-rays using an array of detector elements, arranged so that each of the elements receives the scattered X-rays at one of the plurality of scattering angles.

19. The method according to claim 18, wherein receiving the scattered X-rays comprises generating, at each of the detector elements on which one of the X-rays is incident, a charge signal that is indicative of a photon energy of the one of the X-rays, and wherein analyzing the detected X-rays comprises determining the photon energies of the incident X-rays responsively to an amplitude of the charge signal.

20. The method according to claim 19, wherein analyzing the detected X-rays comprises counting X-ray photons that are incident on the detector elements at each of the first and second photon energies so as to determine the scattering profile at each of the photon energies.

21. The method according to claim 14, wherein analyzing the detected X-rays comprises determining the scattering profile as a function of azimuthal angle in a plane of a surface of the sample.

22. The method according to claim 21, wherein analyzing the detected X-rays comprises determining the scattering profile due to a porous surface layer that overlies a

substrate of the sample, and estimating, based on the scattering profile, one or more characteristics of pores located within the porous surface layer.

23. The method according to claim 22, wherein estimating the one or more characteristics comprises determining the one or more characteristics so as to fit the scattering profile at both the first energy and the second energy.

24. The method according to claim 14, wherein the sample comprises a semiconductor wafer, and wherein analyzing the detected X-rays comprises determining the scattering profile due to a thin film layer on the wafer.

25. Apparatus for inspection of a sample, comprising:

a radiation source, which is adapted to irradiate an area on a surface of the sample with a polychromatic beam of X-rays, comprising at least first X-rays and second X-rays having distinct, respective first and second photon energies;

an array of detector elements arranged to receive the first and second X-rays scattered from the sample at a plurality of scattering angles, and to generate a signal responsively to the received radiation; and

a signal processor, which is coupled to process the signal from the detector elements so as to determine a scattering profile of the sample at the first and second photon energies.

26. The apparatus according to claim 25, wherein the radiation source comprises a collimator, which is adapted to collimate the beam of X-rays.

27. The apparatus according to claim 25, wherein the radiation source comprises an X-ray tube having an anode

comprising an anode material, wherein the first and second photon energies correspond to first and second atomic emission lines of the anode material.

28. The apparatus according to claim 27, wherein the anode material comprises first and second elements, which generate the first and second atomic emission lines, respectively.

29. The apparatus according to claim 25, wherein each of the detector elements is adapted to generate, upon incidence of one of the X-rays thereon, a charge signal that is indicative of a photon energy of the one of the X-rays, and wherein the signal processor is adapted to determine the photon energies of the incident X-rays responsively to an amplitude of the charge signal.

30. The apparatus according to claim 29, wherein the signal processor is adapted to count X-ray photons that are incident on the detector elements at each of the first and second photon energies so as to determine the scattering profile at each of the photon energies.

31. The apparatus according to claim 25, wherein the array of detector elements has is arranged to resolve the received X-rays along an array axis parallel to a surface of the sample, and wherein the signal processor is adapted to determine the scattering profile as a function of azimuthal angle in a plane of the surface responsively to the signal from the detector elements.

32. The apparatus according to claim 31, wherein the signal processor is adapted to determine the scattering profile due to a porous surface layer that overlies a substrate of the sample, and to estimate, based on the

scattering profile, one or more characteristics of pores located within the porous surface layer.

33. The apparatus according to claim 32, wherein the signal processor is adapted to estimate the one or more characteristics so as to fit the scattering profile at both the first energy and the second energy.

34. The apparatus according to claim 25, wherein the sample comprises a semiconductor wafer, and wherein the signal processor is adapted to determine the scattering profile due to a thin film layer on the wafer.

35. Apparatus for inspection of a sample, comprising:

a radiation source, which is adapted to irradiate an area on a surface of the sample with a polychromatic beam of X-rays, comprising X-ray photons having a range of respective photon energies;

an array of detector elements arranged to receive the X-rays scattered from the sample at a plurality of scattering angles, and to generate output signals indicative of the respective photon energies of the X-ray photons that are incident thereon; and

a signal processor, which is coupled to process the output signals so as to determine a scattering profile of the sample at a selected photon energy within the range.

36. The apparatus according to claim 35, wherein the radiation source comprises a collimator, which is adapted to collimate the beam of X-rays.

37. The apparatus according to claim 35, wherein the signal processor is adapted to determine the scattering profile at selected, first and second photon energies within the range.

38. The apparatus according to claim 37, wherein the radiation source comprises an X-ray tube having an anode comprising an anode material, wherein the first and second photon energies correspond to first and second atomic emission lines of the anode material.

39. The apparatus according to claim 38, wherein the anode material comprises first and second elements, which generate the first and second atomic emission lines, respectively.

40. The apparatus according to claim 35, wherein the signal processor is adapted to count X-ray photons that are incident on the detector elements at the selected photon energy.

41. The apparatus according to claim 40, wherein the array of detector elements comprises a readout circuit that is common to a multiplicity of the detector elements, and which is adapted to read out a charge generated in each of the detector elements due to the scattered X-rays that are incident thereon, and wherein the signal processor is adapted to process the charge read out by the readout circuit in order to count the X-ray photons at the selected photon energy.

42. The apparatus according to claim 40, wherein the detector elements are adapted to generate pulses responsively to the scattered X-rays that are incident thereon, and wherein the signal processor is adapted to process the pulses in order to count the X-ray photons at the selected photon energy.

43. The apparatus according to claim 35, wherein the array of detector elements is further adapted to receive

the X-rays reflected from the sample over multiple elevation angles, and wherein the signal processor is further adapted to process the output signals based on the photon energies so as to determine a reflectometric profile of the sample at the selected photon energy.

44. The apparatus according to claim 35, wherein the array of detector elements has is arranged to resolve the received X-rays along an array axis parallel to a surface of the sample, and wherein the signal processor is adapted to determine the scattering profile as a function of azimuthal angle in a plane of the surface responsively to the output signals.

45. The apparatus according to claim 44, wherein the signal processor is adapted to determine the scattering profile due to a porous surface layer that overlies a substrate of the sample, and to estimate, based on the scattering profile, one or more characteristics of pores located within the porous surface layer.

46. The apparatus according to claim 35, wherein the sample comprises a semiconductor wafer, and wherein the signal processor is adapted to determine the scattering profile due to a thin film layer on the wafer.

47. A cluster tool for producing microelectronic devices, comprising:

a deposition station, which is adapted to deposit a thin-film layer on a surface of a semiconductor wafer;

an inspection station, comprising:

a radiation source, which is adapted to irradiate an area on a surface of the wafer with a polychromatic beam of X-rays, comprising at least

first X-rays and second X-rays having distinct, respective first and second photon energies;

an array of detector elements arranged to receive the first and second X-rays scattered from the wafer at a plurality of scattering angles, and to generate a signal responsively to the received radiation; and

a signal processor, a signal processor, which is coupled to process the signal from the detector elements in order to determine a scattering profile of the wafer at the first and second photon energies, so as to assess a quality of the thin-film layer deposited by the deposition station.

48. A cluster tool for producing microelectronic devices, comprising:

a deposition station, which is adapted to deposit a thin-film layer on a surface of a semiconductor wafer;

an inspection station, comprising:

a radiation source, which is adapted to irradiate an area on a surface of the wafer with a polychromatic beam of X-rays, comprising X-ray photons having a range of respective photon energies;

an array of detector elements arranged to receive the X-rays scattered from the wafer at a plurality of scattering angles, and to generate output signals indicative of the respective photon energies of the X-ray photons that are incident thereon; and

a signal processor, which is coupled to process the output signals in order to determine a scattering profile

of the wafer at a selected photon energy within the range, so as to assess a quality of the thin-film layer deposited by the deposition station.

49. Apparatus for producing microelectronic devices, comprising:

a production chamber, which is adapted to receive a semiconductor wafer;

a deposition device, which is adapted to deposit a thin-film layer on a surface of the semiconductor wafer within the chamber;

a radiation source, which is adapted to irradiate an area on a surface of the wafer with a polychromatic beam of X-rays, comprising at least first X-rays and second X-rays having distinct, respective first and second photon energies;

an array of detector elements arranged to receive the first and second X-rays scattered from the wafer at a plurality of scattering angles, and to generate a signal responsively to the received radiation; and

a signal processor, which is coupled to process the signal from the detector elements in order to determine a scattering profile of the wafer at the first and second photon energies, so as to assess a quality of the thin-film layer deposited by the deposition device.

50. Apparatus for producing microelectronic devices, comprising:

a production chamber, which is adapted to receive a semiconductor wafer;

a deposition device, which is adapted to deposit a thin-film layer on a surface of the semiconductor wafer within the chamber;

a radiation source, which is adapted to irradiate an area on a surface of the wafer with a polychromatic beam of X-rays, comprising X-ray photons having a range of respective photon energies;

an array of detector elements arranged to receive the X-rays scattered from the wafer at a plurality of scattering angles, and to generate output signals indicative of the respective photon energies of the X-ray photons that are incident thereon; and

a signal processor, which is coupled to process the output signals in order to determine a scattering profile of the wafer at a selected photon energy within the range, so as to assess a quality of the thin-film layer deposited by the deposition device.